EGU21-16139
https://doi.org/10.5194/egusphere-egu21-16139
EGU General Assembly 2021

Assessing the constraint of the CO2 monitoring mission on fossil fuel emissions from power plants and a city in a regional carbon cycle fossil fuel data assimilation system

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The Paris Agreement foresees to establish a transparency framework that builds upon inventory-based national greenhouse gas emission reports, complemented by independent emission estimates derived from atmospheric measurements through inverse modelling. The capability of such a Monitoring and Verification Support (MVS) capacity to constrain fossil fuel emissions to a sufficient extent has not yet been assessed. The CO2 Monitoring Mission (CO2M), planned as a constellation of satellites measuring column-integrated atmospheric CO2 concentration (XCO2), is expected to become a key component of an MVS capacity.

Here we present a CCFFDAS that operates at the resolution of the CO2M sensor, i.e. 2km by 2km, over a 200 km by 200 km region around Berlin. It combines models of sectorial fossil fuel CO2 emissions and biospheric fluxes with the Community Multiscale Air Quality model (coupled to a model of the plume rise from large power plants) as observation operator for XCO2 and tropospheric column NO2 measurements. Inflow from the domain boundaries is treated as extra unknown to be solved for by the CCFFDAS, which also includes prior information on the process model parameters. We discuss the sensitivities (Jacobian matrix) of simulated XCO2 and NO2 troposheric columns with respect to a) emissions from power plants, b) emissions from the surface and c) the lateral inflow and quantify the respective contributions to the observed signal. The Jacobian representation of the complete modelling chain allows us to evaluate data sets of simulated random and systematic CO2M errors in terms of posterior uncertainties in sectorial fossil fuel emissions. We provide assessments of XCO2 alone and in combination with NO2 on the posterior uncertainty in sectorial fossil fuel emissions for two 1-day study periods, one in winter

and one in summer. We quantify the added value of the observations for emissions at a single point, at the 2km by 2km scale, at the scale of Berlin districts, and for Berlin and further cities in our domain. This means the assessments include temporal and spatial scales typically not covered by inventories. Further, we quantify the effect of better information of atmospheric aerosol, provided by a multi-angular polarimeter (MAP) onboard CO2M, on the posterior uncertainties.

The assessments differentiate the fossil fuel CO2 emissions into two sectors, an energy generation sector (power plants) and the complement, which we call “other sector”. We find that XCO2 measurements alone provide a powerful constraint on emissions from larger power plants and a constraint on emissions from the other sector that increases when aggregated to larger spatial scales. The MAP improves the impact of the CO2M measurements for all power plants and for the other sector on all spatial scales. Over our study domain, the impact of the MAP is particularly high in winter. NO2 measurements provide a powerful additional constraint on the emissions from power plants and from the other sector.